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Localized particle production in the beam and target fragmentation regions

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Results are presented from three high-energy reactions that pertain to hadron production from excited beam and target particles when angular distributions are viewed in a particular frame. These results are discussed in light of a recent conjecture concerning the angular asymmetry expected from particle emission from a localized area on the emitting hadron.

A model of hadron production in peripheral high-energy collisions suggested by Weiner[1,2] has received support from an analysis of the reaction $K^-p \to K^-p\pi^+\pi^-$ at 14 GeV.[3] In this model, particle production is viewed as taking place from a localized point on the emitting hadron. One of the consequences of this process is an asymmetry in the angular distribution of the emitted particles when viewed in the rest frame of the excited hadrons. We have examined the reactions

(1) $\pi^+p \to \pi_f^+\pi^-\pi_s^+p$,

(2) $\pi^-p \to \pi_f^-\pi^+\pi_s^-p$,

(3) $\pi^+p \to K^+p\pi^+K^-$

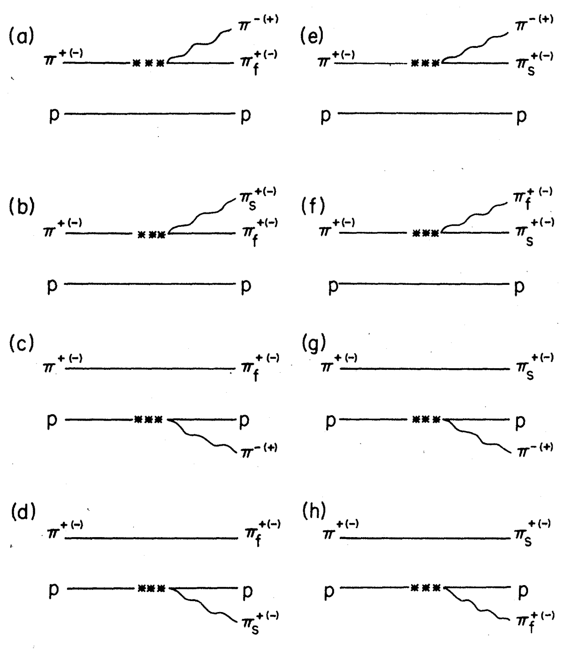

FIG. 1. All possible schematic diagrams used in defining the coordinate system for reactions (1) and (2). The superscripts in parentheses apply to reaction (2). $\pi_f^{+(-)}$ and $\pi_s^{+(-)}$ refer to the fast and slow identical pions ordered by c.m.s. longitudinal momenta. The asterisks denote the excited hadron which subsequently radiates a pion.

for similar effects in beam or target excitation. The subscripts f and s refer to the faster and slower pions as ordered by their longitudinal momenta in the center-of-mass system (c.m.s.).

Data from three different experiments have been employed in our analysis. The samples examined consisted of 43 429 events for reaction (1), 22 410 events for reaction (2), and 12 846 events for reaction (3), where beam momenta were 13.1, 13.2, and 11.5 GeV/c, respectively. All experiments were performed at SLAC, the first two using the 82-in. bubble chamber and the third using the 40-in. Hybrid facility. Data from reactions (1) and (2) have been reported previously.[4,5,6] Events for reaction (3) were obtained from 1.2×10^6 pictures using an on-line algorithm to trigger an exposure for fast downstream particles heavier than a pion. All results from this experiment have been corrected for acceptance. Details of this data reduction will be presented elsewhere.

We have analyzed our data by the method outlined in Ref. 3. Particle emission is presumed to take place from the scattered beam (target). The coordinate system is defined in the rest frame of the scattered beam (target) and the emitted hadron, where the $\hat{y}$ axis is given by the target

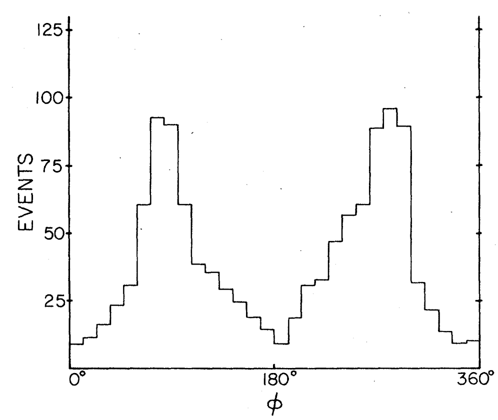

FIG. 2. Azimuthal angle ϕ for π^- radiated from the p in reaction (1).

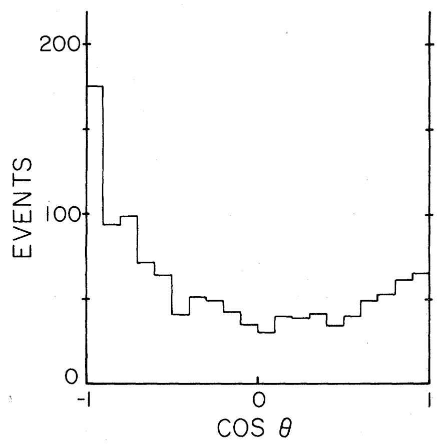

FIG. 3. Cosine of the polar angle for the π^- radiated from the p in reaction (1).

(beam) direction and the $\hat{x}$ axis is the cross product of the $\hat{y}$ axis into the scattered target (beam) direction; the $\hat{z}$ axis is then $\hat{x}\times\hat{y}$. Diagrams in Fig. 1 illustrate the particles involved in the definitions of these frames for reactions (1) and (2). The utility of this scheme is that for peripheral events the positive $\hat{z}$ axis is in the same direction as the three-momentum transfer. It is natural to assume that any angular asymmetry would manifest itself in the distributions about this axis. To assure that the events were peripheral, the requirements that the scattered beam particles have center-of-mass longitudinal rapidity greater than 1.5 and that the rapidity of the scattered target be less than −1.2 were invoked. Variation of these cuts did not significantly affect our final results.

The existence of identical particles in the final states of the first two reactions complicates the analysis. Monte Carlo calculations using phase-space events show that assuming the pion (whose charge is the same as that of the beam) with the largest rapidity is the scattered beam, introduces an asymmetry in the polar-angle distributions. This problem may be avoided by combining the distributions found using first the fast and then the slow pion as the scattered beam. This procedure eliminates the asymmetry introduced by the kinematical cuts on the ordered pions.

The angular distributions defined in Ref. 3 were plotted for those events for which the ratio of the rapidities of the emitted to emitting hadron was between 0.7 and 1.5. In Figs. 2 and 3 the azimuthal and polar-angle distributions are shown for the π^- emitted from the proton in reaction (1) [see Fig. 1(c)]. Both are typical of the two-body correlations observed in all three reactions. ϕ distributions are symmetric, though not isotropic. Polar-angle distributions, however, yielded varying asymmetries depending on the particles involved. The asymmetry parameter η is defined as

$$\eta=\frac{N_{\rm up}-N_{\rm down}}{N_{\rm up}+N_{\rm down}}\,,$$

TABLE I. Up-down asymmetry η of the emitted hadron in the reaction $\pi^+p\rightarrow\pi_f^+\pi^-\pi_s^+p$ for the rapidity ratio interval $0.7<\rho<1.5$ of Ref. 3.

	Emitted hadron	Emitting hadron	y axis	Scattered beam (target)	η
(A)	π^-	π_f^+	target	p	-0.05 ± 0.02 [a]
(B)	π_s^+	π_f^+	target	p	0.08 ± 0.02 [a]
(C)	π^-	p	beam	π_f^+	-0.23 ± 0.03
(D)	π_s^+	p	beam	π_s^+	-0.01 ± 0.02 [a]
(E)	π^-	π_s^+	target	p	-0.10 ± 0.06 [a]
(F)	π_f^+	π_s^+	target	p	-0.11 ± 0.02 [a]
(G)	π^-	p	beam	π_s^+	-0.14 ± 0.19
(H)	π_f^+	p	beam	π_s^+	b
(I) [c]	π^-	(π_f^+,π_s^+)	target	p	-0.05 ± 0.02
(J)	π_s^+	π_s^+	target	p	-0.01 ± 0.01
	π_f^+	π_f^+			

[a] Value may be affected by particle ordering.
[b] Insufficient data.
[c] See text for explanation.

TABLE II. Up-down asymmetry η of the emitted hadron in the reaction $\pi^- p \to \pi_f^- \pi^+ \pi_s^- p$ for the rapidity ratio interval $0.7 < \rho < 1.5$ of Ref. 3.

	Emitted hadron	Emitting hadron	y axis	Scattered beam (target)	η
(A)	π^+	π_f^-	target	p	-0.03 ± 0.02 [a]
(B)	π_s^-	π_f^-	target	p	0.11 ± 0.02 [a]
(C)	π^+	p	beam	π_f^-	-0.15 ± 0.03
(D)	π_s^-	p	beam	π_f^-	-0.12 ± 0.03 [a]
(E)	π^+	π_s^-	target	p	-0.04 ± 0.07 [a]
(F)	π_f^-	π_s^-	target	p	-0.16 ± 0.02 [a]
(G)	π^+	p	beam	π_s^-	-0.03 ± 0.11
(H)	π_f^-	p	beam	π_s^-	b
(I) [c]	π^+	(π_f^-, π_s^-)	target	p	-0.03 ± 0.02
(J)	π_s^-	π_f^-	target	p	-0.02 ± 0.02
	π_f^-	π_s^-			

[a] Value may be affected by particle ordering.
[b] Insufficient data.
[c] See text for explanation.

where N_{up} is the number of events with polar angles less than $\pi/2$ and N_{down} is the number with angle greater than $\pi/2$. Results for all three reactions are summarized in Tables I, II, and III. The first column gives the particle whose momentum is used as the analyzer in the rest frame of the emitted and emitting (column 2) hadrons. The $\hat{y}$ axis is defined by the direction of the particle listed in column 3. For the first two reactions there are eight possible two-body correlations. (In addition, the combined distributions found by interchanging slow and fast pions have been included.) In most cases there exists a downwards asymmetry which has been interpreted as evidence for particle radiation from a localized "hot spot" on the emitting hadron.

In order to better understand these observations, we assess the effect of the rapidity cuts made on the emitted and emitting hadrons. Define ρ to be the ratio of the rapidity of the emitted hadron to that of the emitting particle.[3] In Fig. 4, η versus ρ is shown over the range $0 \leq \rho \leq 2$ for the π^- in reaction (1) associated with the proton. For ρ less than 1, η is negative and relatively constant. Above this point η rises to slightly positive value. This same dependence is even more prominent in Fig. 5 where η is shown for the combined distributions of the π^- associated with the π_f^+ and π_s^+. This behavior is characteristic of all the asymmetric distributions considered. The results shown in Table III for the third reaction are puzzling in that they resemble those from the other processes even though this channel is manifestly not diffractive.

An interpretation of the asymmetry seen is problematic because of the dominance of resonance production for the majority of events. This is exhibited by an examination of the mass distribu-

TABLE III. Up-down asymmetry η of the emitted hadron in the reaction $\pi^+ p \to K^+ p \pi^+ K^-$ for the rapidity ratio interval $0.7 < \rho < 1.5$ of Ref. 3.

	Emitted hadron	Emitting hadron	y axis	Scattered beam (target)	η
(A)	π^+	K^+	target	p	-0.14 ± 0.10
(B)	K^-	K^+	target	p	-0.01 ± 0.09
(C)	π^+	p	beam	K^+	-0.03 ± 0.06
(D)	K^-	p	beam	K^+	a

[a] Insufficient data.

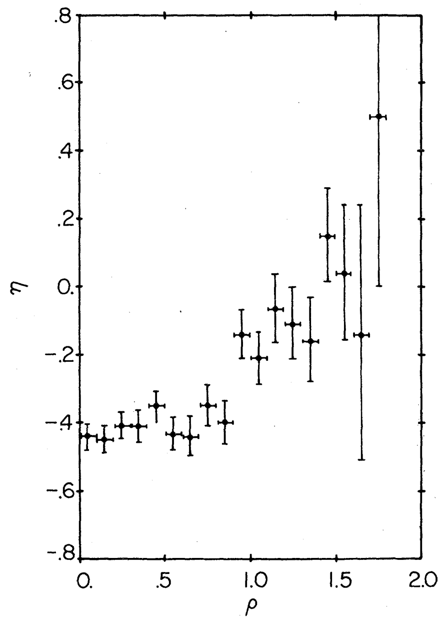

FIG. 4. Asymmetry parameter η as a function of the ratio of the rapidity to the π^- to that of the p in reaction (1).

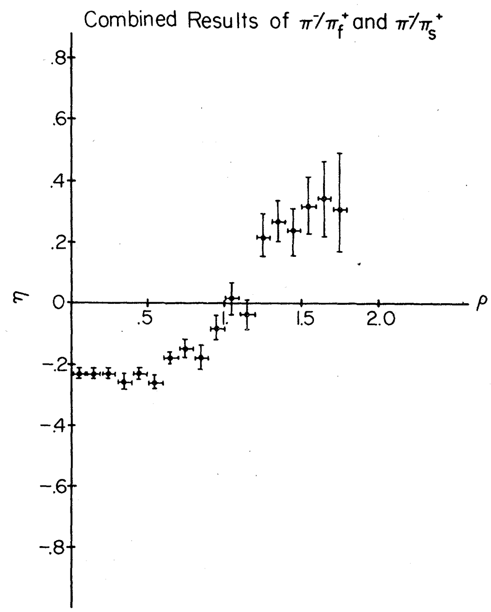

FIG. 5. Combined results for the asymmetry parameter η as a function of the ratio of the rapidity of the π^- to the π_f^+ and π_s^+ in reaction (1).

tions from all three reactions. We consider first reactions (1) and (2). In all cases where a π^+ is associated with the scattered proton, a strong Δ^{++} signal is seen. In like fashion, ρ^0, f^0, and g^0 are seen in the mass spectra of the $\pi^-(\pi)$ associated with a scattered $\pi^+(\pi^-)$. The case of like signed pions shows strong ρ^0 production for the scattered beam unlike signed pion. The three meson mass-distribution peaks at low mass are indicative of inelastic diffractive production. Channel (A) of reaction (3) (see Table III) shows both f^0/A_2 production and K^{*0} (890). Channel (B) is dominated by f^0/A_2 being formed opposite the Δ^{++}. This same behavior is also noted for channel (C). We may summarize these results by noting that the prism-plot analysis of Ref. 6 shows that virtually all events of reaction (2) may be attributed to resonance production or diffractive excitation. It is therefore difficult to unravel the effect of this natural background upon the angular distributions presented. If it is assumed that the emitted pions are radiated away in some quasi-thermodynamic fashion, then final-state interactions must be invoked to explain the copious resonant formations.

It is difficult to reconcile our findings with the process outlined in the first two references. The same effect is seen in both diffractive and non-diffractive reactions. More serious is the change in sign of the asymmetry with large ρ. In Figs. 4 and 5 we note the rapid variation of the asymmetry η through the region $0.7<\rho<1.5$ of Ref. 3; either the sign of the interactions change (from attractive to repulsive) of the effect is a result of kinematical cuts used to isolate the various event samples. An interpretation of η averaged over this interval of ρ is dubious. Furthermore, in this kinematical range we observe similar negative values of the asymmetry η even though the $\pi^{\pm}p$ interaction is repulsive. We conclude that these results provide no persuasive evidence for localized particle production.

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[1]R. M. Weiner, Phys. Rev. Lett. 32, 630 (1974).
[2]R. M. Weiner, Phys. Rev. D 13, 1363 (1976).
[3]J. Goldberg, Phys. Rev. Lett. 43, 250 (1979).
[4]G. Thompson *et al.*, Phys. Rev. D 9, 560 (1974).
[5]G. Thompson *et al.*, Phys. Rev. Lett. 32, 331 (1974).
[6]J. A. Gaidos and W. L. Yen, Phys. Rev. D 19, 22 (1979).